High Data Rate Lasers for Free Space Optical Communications

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Free space laser communication technology has been under development for the past several years at the NASA, Jet Propulsion Laboratory. In comparison to RF communication systems, optical communications offer bandwidth advantages supporting higher data rates (up to several Gbps) and much smaller beam divergence. For spaceborne applications, the smaller transmit aperture can lead to reduced terminal mass and power requirements which translates directly into lower payload launch costs. A further advantage over existing and future microwave technology is the lack of frequency allocation requirements for laser wavelengths. The challenge for laser communications is the stringent pointing requirements imposed by the narrow beamwidth, cloud blockages and atmospheric induced scintillation effects.

The JPL/NASA optical communications requirements are driven firstly by the need for high-data-rate communications from low-Earth orbiters to GEO to ground, and secondly by lower data rate (100 kbps-10 Mbps) communications from deep space probes. Although there are areas of overlap between these communications scenarios, the arenas can be differentiated by the requirements on the laser source and data detector. The much larger distances for deep space communications require high photon efficiency which is attained by utilizing high peak power lasers, greater than MW/pulse. Diode pumped solid state lasers using a pulse position modulation (PPM) format with data rates less than Mbps are well suited to such applications. Near earth applications on the other hand do not require as high photon efficiencies and can provide data rates up to several Gbps with a few Watts average power. Direct diode and fiber based master-oscillator power-amplifier (MOPA) type devices are potential candidates for these LEO or GEO based systems.

The current architecture of the terminal for both near-Earth and deep space optical communications is based on the JPL's Optical Communications Demonstrator. The design is flexible enough, so that when it is gimbal-mounted it can support high data rate near-Earth communications while on deep space missions it would mate directly with the spacecraft.

Although an overview of different laser communications systems for various NASA missions will be presented, this talk will focus on high data rate lasers that satisfy near-Earth mission requirements. To be competitive with new RF modulation techniques, high-data-rate communications to and from geostationary platforms will require high-power, high-efficiency lasers with excellent beam quality. Fiber based sources are not as efficient as diodes. However, due to the long excited state lifetimes, fiber sources have comparable efficiencies under high-speed modulation. Performance of laboratory prototypes of fiber and diode based MOPAs developed by SDL under SBIR contracts will be reported in this presentation.

The first is a two-stage diode pumped fiber amplifier based on dual clad Yb-doped fiber technology which emits 4 W of average power at 1072 nm and is capable of supporting 2.5 Gbps data rate. A schematic is shown in Fig. 1. The delivered system also included an optically pre-amplified detector to evaluate link performance. The semiconductor MOPA with flared amplifier is shown in Fig. 2 and emits greater than 1 W at 935 nm with data rates up to 2.5 Gbps possible also. Eye patterns before and after clock and data recovery are shown in Fig. 3. Preliminary characterization studies include BER performance and eye-diagrams under high-speed modulation as well as a discussion on the modulation extinction ratio requirements.

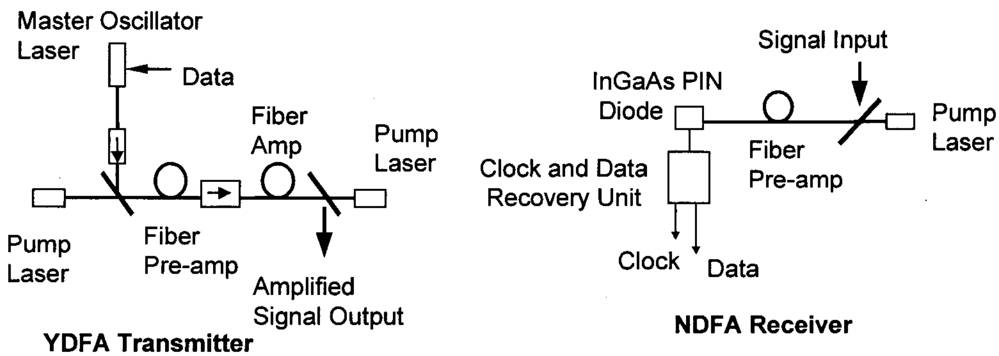

Figure 1 Schematic of fiber based MOPA telecommunication link

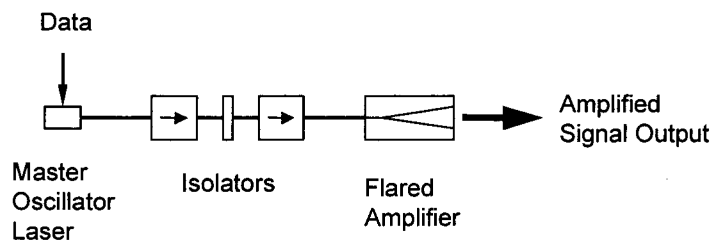

Figure 2 Schematic of discrete diode MOPA transmitter